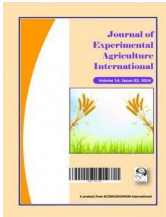

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Comparison of the Physicochemical Properties of Aubergine (Solanaceae) Varieties *Solanum aethiopicum gilo* and *Solanum melogena* Grown in Northern Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aubergines are common vegetables widely consumed by populations in various meals. Unfortunately, these legumes are not soundly investigated whereas their properties are known to be influenced by environmental conditions. The current work focuses the physico-chemical traits of two aubergines, namely *Solanum aethiopicum gilo* and *Solanum melogena* usually produced and marketed in Northern Côte d'Ivoire for better valorisation.

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From both aubergines fruits sampled from the main local markets, the comparative physicochemical properties reveal higher size, weight and protein content for *S. melogena*, with respective values of 15.51±1.73 cm, 161.21±33.82 g, and 1.81±0.06%. With *S. aethiopicum gilo*, greater contents are recorded for reducing carbohydrates (0.18±0.02%), phytates (27.74±0.86 mg/100 g), and oxalates (36.85±5.63 mg/100 g). Besides, the median circumference and the contents in moisture, fat, total carbohydrates, crude fibre, vitamin C, polyphenols, ash and mineral elements, as well as the total caloric energy value of both raw food products are not statistically different at 5% significance. The study strengthens the dietary fibre and natural polyphenols and minerals intake from the consumption of these aubergines although phytates and oxalates are recovered within as antinutrients components.

Keywords: Aubergine; Solanum aethiopicum gilo; Solanum melogena; physico-chemical properties; Korhogo.

1. INTRODUCTION

Aubergine (*Solanum melogena*), chili pepper (*Capsicum* spp.) and tomato (*Solanum lycopersicum*) are among the forty (40) most produced vegetable species in the world [1]. According to statistics from the United Nations Food and Agriculture Organization, world production of S. melogena is estimated at 49.4 million tons, tomato production is estimated at 164.5 million tons when chili production is of 8.8 million tons.

However, the aubergine variety *Solanum aethiopicum gilo* is not rather known over the world. This aubergine variety is of the fruit vegetables that are most commonly grown and consumed in tropical Africa and therefore spelled ''African aubergine''. According to Lester and Seck [2], it is ranked third in terms of legumes consumption after tomatoes, onions and okra. From sub-Saharan Africa, these authors estimated annual fruit production for 4,500 tons in Burkina Faso, 8,000 tons in Senegal, and 60,000 tons in Côte d'Ivoire.

The plant species *S. aethiopicum gilo* originates from Africa, while the running aubergine (*S. melogena*) is an Asian originated product. Both of these plants are grown in Côte d'Ivoire, where their fruits and leaves are usually eaten by populations [3]. Specifically, in Korhogo, northern Côte d'Ivoire, these vegetables are mostly grown by women but also by local young men seeking to find incomes and fit their livelihoods. This crop is grown in slopes of lower or larger dams in northern Côte d'Ivoire [4].

The aubergines raw products are used for the preparation of sauces and consumed with rice and pounded meals such as local ‘*’foufou’’* or ‘*’foutou’’*. They are also intrant ingredients for the preparation of ‘‘*Tchepodjen’’*, a rice meal originating from Senegal. The aubergines are considered as raw product with significant antioxidant activity and hypotensive and diuretic effects [5,6].

However, scanty laboratory research information is known from the aubergines varieties *Solanum melogena* and *Solanum aethiopicum gilo*. Unfortunately, many aubergines remain unsold and still rotting in numerous markets once harvested and conveyed for the sale. The current study is attempted to provide data regarding the physicochemical properties of both aubergines and thus to contribute in their valorisation.

2. MATERIALS AND METHODS

2.1 Material

The works were achieved on aubergines fruits deriving from *Solanum aethiopicum gilo* and *Solanum melogena* species. Both aubergines are usually produced in Korhogo, northern Côte d'Ivoire.

2.2 Methods

2.2.1 Sampling

The aubergines samples were purchased from three (3) main markets of Korhogo, namely ''Sinistré'' market, ''Soba'' market, and ''Koko'' market. Per market, 10 kg sample of each aubergine were purchased from three various sellers. Thus, 30 kg of each aubergine were gathered per market, leading to 180 kg (30 kg *2 varieties *3 markets) for overall aubergine samples purchased. The samples were then conveyed into laboratory for further analyses.

2.2.2 Physical Characterisation of *Solanum aethiopicum gilo* and *Solanum melogena*

Five (5) physical parameters were assessed on the aubergine fruits, namely length, circumference, weight, moisture, and ash.

The length and the circumference of the full fruit were estimated using a meter tape, and allowed the deduction of the general fruit shape. The fruit weight was measured using a 2 digits scale (Sartorius).

The method used for determining the moisture was that suggested by AOAC [7]. The moisture was assessed by drying 5 g of aubergine into an oven at 105°C till constant weight resulted after 24 h. The ash content was measured by incinerating five (5) g of oven-dried aubergine into a muffle furnace at 550°C for 12 h.

2.2.3 Determination of the chemical trend of the aubergine fruits

2.2.3.1 Acidity

The acidity traits (pH and titratable acidity) were measured using AOAC methods [7]. Ten (10) grams of crushed sample were slurried in 100 mL of distilled water. The resulting solution was filtered on Whatman micropore filter paper. The pH was thus directly measured out by immersing the previously calibrated pH meter (HANNA) electrode in the filtrate. However, 10 mL of the filtrate were taken and titrated with a NaOH solution (0.1 N) in the presence of phenolphthalein. The NaOH measure used to result in a persistent pink colour has allowed the deduction of the titratable acidity given in mEq/100g of dried sample.

2.2.3.2 Total soluble carbohydrates and reducing carbohydrates contents

Ethanosoluble carbobydrates were extracted from 1 g of ground dried aubergine with 20 mL of 80% (v/v) ethanol, 2 mL of 10% (m/v) zinc acetate and 2 mL of 10% (m/v) oxalic acid, according to the method of Agbo et al. [8]. The extract was centrifuged at speed of 3,000 rpm for 10 min. The ethanol residue was evaporated from the extract upon a hot sand bath.

Then, the extracted total soluble carbohydrates were measured out using the method of Dubois et al. [9]. The operation consisted in adding 0.9 mL of distilled water, 1 mL of 5% (m/v) phenol, and 5 mL of 96% sulfuric acid into 100 µL of extract, then measuring the absorbance at 490 nm with a spectrophotometer (PG instruments). For the reducing sugars, 1 mL of extract was processed with 0.5 mL of distilled water and 0.5 mL of 3, 5- dinitrosalycilic acid [10] prior to the recording of the absorbance from the final solution at 540 nm with a spectrophotometer (PG instruments).

Calibrations were performed with standard solutions of glucose and sucrose for recovering the final total carbohydrates and reducing carbohydrates contents in the studied samples.

2.2.3.3 Lipids content

Lipids were quantified from 10 g of ground dried aubergine sample by solvent extraction using 300 mL of n-hexane reagent and a Soxhlet device for 7 h [11]. The hexan-oil mixture resulted from the extraction was recovered and separated with a rotavapor apparatus (Heidolph). The difference between the sample weight before and after the experiment allowed the estimation of the lipids content.

2.2.3.4 Proteins content

Crude proteins content was determined as the total nitrogen using the Kjeldhal method [7]. Thus, 1 g of aubergine mash was mineralised at 400°C for 2 h, with adding of concentrated sulfuric acid (H_2SO_4) and potassium sulfate (K_2SO_4) catalyst. The mineralisate was diluted and distilled for 10 min. Thereafter, the distillate collected into a flask containing boric acid and methylen bromocresol reagents ion, was titrated for the total nitrogen using ammonium sulfate ($(NH_4)_2SO_4$). The crude protein content of the aubergine was deduced from the nitrogen level using 6.25 as conversion coefficient.

2.2.3.5 Fibers content

The determination of the crude fibres content consisted in the treatment of 2 g of ground aubergine sample with 50 mL of 0.25N sulfuric acid and 50 mL of 0.31 N sodium hydroxide and filtration of the resulting solution upon Whatman paper. The residue was dried for 8 h at 105°C then incinerated at 550°C for 3 h into ovens [12]. The final residue was weighed as crude fibres and expressed in percentage.

2.2.3.6 Total carbohydrates content and energy value

Total carbohydrates and energy values were determined using calculation formulas [13] accounting the moisture, fat, protein, ash contents and the energetic coefficients for macromolecules.

$$TCC\ (\%) = 100-[P(\%) + W(\%) + F(\%)+A(\%)]$$
$$CEV\ (kcal/100g) = [(4\times P) + (9\times F) + (4\times C)]$$

With: TCC, total carbohydrates content; CEV, caloric energy value; P, protein content; M, moisture content; F, fat content; A, ash content; C, total carbohydrates content

2.2.3.7 Polyphenols contents

The phenol compounds were extracted from aubergine with methanol reagent. One gram of dried aubergine sample was homogenised in 10 mL of methanol solution 70% (v/v). The resulting mixture was centrifuged at 1,000 rpm for 10 min. The pellet was recovered and treated likewise. The deriving supernatants were thus gathered into a marked flask and added with distilled water at 50 ml.

The total polyphenols content was measured using Folin-ciocalteu reagent, sodium carbonate solution (20% w/v) and distilled water [14]. Essays were measured for their absorbance at 745 nm with a spectrophotometer against standard gallic acid solutions taken as polyphenols control.

The tannins content was deducted from the total polyphenols using vanillin reagent [15]. Essays were measured for their absorbance at 500 nm with a spectrophotometer against standard tannic acid solutions taken as tannins control.

Flavonoids content was also determined from the total polyphenols using aluminium chloride (10% w/v), potassium acetate (1 M) and distilled water [16]. Essays were measured for their absorbance at 415 nm with a spectrophotometer against standard quercetin solutions taken as flavonoids control.

2.2.3.8 Vitamin C content

The vitamin C was evaluated from the aubergines using 2,6- dichlorophenol-indophenol (DCPIP) reagent [17]. Ten (10) grams of ground dried aubergine sample were dissolved into 40 mL of metaphosphoric acid-acetic acid solution (2%, w/v). The resulted mixture was centrifuged at 3,000 rpm for 20 min. Thus, the supernatant was recovered, added with boiled distilled water for 50 mL, and titrated with 2, 6- DCPIP solution (0.5 g/L) previously calibrated with a pure vitamin C solution.

2.2.3.9 Oxalates content

The oxalate content was determined with the standard AOAC method [7]. Two (2) grams of ground dried aubergine sample were homogenised into 200 mL of distilled water and added with 20 mL of 6N hydrochloric acid (HCl). The mixture was heated in boiling water bath for 1 h, cooled, and filtered. Fifty (50) mL of the filtrate were then homogenised into 20 mL of 6 N HCl, and filtered again. The 2nd filtrate was treated with methyl red (0.1%, w/v), concentrated ammonia, heated, and filtered. The 3rd filtrate was boiled, treated with calcium chloride (5%, w/v) for the formation of calcium oxalate crystals, and then filtered once more. The residues deriving from the filtration steps were successively washed with distilled boiling water, dried into an oven; dissolved into 10 mL of diluted sulfuric acid, and titrated with 0.05N potassium permanganate solution.

2.2.3.10 Phytates content

The phytates were measured according to the method processed by Mohammed et al. [18]. A slight ground aubergine sample (0.5 g) was treated with 25 mL of TCA solution at 3% (w/v) and centrifuged at 3,500 rpm for 15 min. Five (5) mL of the supernatant was removed, treated with 3 mL of ferric chloride 1% (w/v) reagent, heated in a boiling water bath, cooled and also centrifuged at 3,500 rpm for 10 min. The 2nd supernatant was treated with 5 mL of 0.5N hydrochloric acid, 5 mL of 1.5N sodium hydroxide, heated in a boiling water bath and centrifuged once more at 3500 rpm for 10 min. Thus, 1 mL of the final supernatant was added with 4.5 mL of distilled water and 4.5 mL of orthophenantroline reagent and then measured for the absorbance at 470 nm with a spectrophotometer against standard Mohr salt solution treated likewise and taken as phytates ferric control.

2.2.3.11 Determination of mineral elements

The determination of the mineral elements was performed according to the IITA method [19].

Finely ground aubergine sample (0.4 g) previously oven dried at 60°C was incinerated into a muffle furnace at 550°C for 3 h. The resulting gray-white ash was cooled, added with 2 mL of half-diluted HCl, placed on a sand bath at 120°C until full evaporation, and then ovened at 105°C for a 1 h. The final dry extract was recovered with 2 mL of half-diluted HCl, filtered, and the resulting filtrate added with distilled water, and lanthanum chloride. The mineral elements in the solution were then measured using Atomic Absorption Spectrometry (AAS 20 type VARIAN).

2.2.4 Statistical analyses

All essays were performed in triplicate. The data collected were statistically analysed using Statistica software (Statistica 7.1) at 95% significance. A statistical Student T- test was performed for the comparison between both aubergines varieties studied regarding each parameter assessed. For each characteristic, the results were expressed as averages followed by the standard deviations. Also, the general averages have been calculated for the characteristics displaying any significant divergence between the studied products.

3. RESULTS AND DISCUSSION

3.1 Physical Characteristics of Aubergines

The aubergine *S. aethiopicum gilo* displays a round shape with flattened ends whereas the aubergine *S. melogena* has an elongated shape. Both aubergines show invarious medium circumference (18.04±0.52 cm) and moisture and ash contents (92.62±0.55% and 0.59±0.25%, respectively). Oppositely, Table 1 shows higher size and weight from *S. melogena* (15.51 cm and 161.21 g) compared to the respective 3.79 cm length and 61.07 g weight of *S. aethiopicum gilo*.

3.2 Major Chemical Composition of Aubergines

Except for the proteins and reducing carbohydrates contents and the acid values, the main chemical traits do not show any obvious divergence between *S. aethiopicum gilo* and *S. melogena* (Table 2). Indeed, *S. melogena* provides more protein content (1.81%) but lower reducing carbohydrates content (0.11%) compared to *S. aethiopicum gilo* (1.68% and 0.18%, respectively). Both aubergines varieties are fairly acid. However, the comparison shows *S. aethiopicum gilo* as a lower acid traits aubergine (pH of 7.67 and titratable acid value of 0.46 mEq/100 g) compared to *S. melogena* (pH of 6.93 and acid value of 0.14 mEq/100 g).

Both studied aubergines provide statistically similar means for the contents in fat matter, total fibre, total carbohydrates, and total glucides, and for the energy value. For those characteristics, the respective general contents averages are 0.12%, 2.35%, 2.11%, and 4.91%, providing 27.69 Kcal/100 g as energy value (Table 2).

3.3 Main Micronutrients, Polyphenols Compounds and Antinutrients Deriving from Aubergines

The micronutrients, secondary metabolites (polyphenols) and antinutrients in the aubergines studied are gathered in Table 3. Both aubergines provide statistically invarious mean values regarding the contents in polyphenols (total polyphenols, tannins, and flavonoids), vitamin C, and mineral elements (phosphorus, potassium, calcium, magnesium, sodium, iron, manganese, zinc, and copper). For polyphenols, the general

Table 1. Some physical parameters of *Solanum aethiopicum gilo* and *Solanum melogena*

Parameters	*S. aethiopicum gilo*	*S. melogena*	T_{-value}	P_{-value}	General average
Shape	Round with flattened ends	Elongated	-	-	
Length (cm)	3.79±0.40^b	15.51±1.73^a	130.96	**<0.001**	
Medium circumference (cm)	18.32±0.40^a	17.77±0.66^a	1.53	0.284	18.04±0.52
Weight (g)	61.07±3.27^b	161.21±33.82^a	26.05	**0.007**	
Moisture (%)	92.45±0.34^a	92.8±0.84^a	0.455	0.537	92.62±0.55
Ash (%)	0.41±0.22^a	0.76±0.23^a	3.790	0.123	0.59±0.25

Per raw, values followed by different lower scripts are statistically different at 5% significance. T_{-value}, value of the statistical Student T- test; P-value, value of the statistical probability test

Table 2. Chemical composition of *Solanum aethiopicum gilo* and *Solanum melogena*

Parameters	*S. aethiopicum gilo*	*S. melogena*	T_{-value}	P_{-value}	General average
pH	7.67±0.01[a]	6.93±0.02[b]	16428.00	**<0.001**	
TTA	0.14±0.02[b]	0.47±0.03[a]	$2.921.10^{33}$	**<0.001**	
TPC (%)	1.68±0.04[b]	1.81±0.06[a]	9.274	**0.038**	
FMC (%)	0.12±0.02[a]	0.12±0.01[a]	0.500	0.519	0.12±0.01
TFC (%)	2.75±0.51[a]	1.96±0.49[a]	3.758	0.125	2.35±0.57
TCC (%)	2.10±0.37[a]	2.12±0.51[a]	0.003	0.959	2.11±0.36
RCC (%)	0.18±0.02[a]	0.11±0.03[b]	20.346	**0.011**	
TGC (%)	5.33±0.18[a]	4.50±0.54[a]	6.313	0.066	4.91±0.53
TEV (Kcal/100g)	29.12±0.67[a]	26.26±2.45[a]	3.793	0.123	27.69±2.05

Per raw, values followed by different lower scripts are statistically different at 5% significance. T_{-value}, value of the statistical Student T- test; P-value, value of the statistical probability test. pH, potential of hydrogen; TTA, total titratable acidity; TPC, total proteins content; FMC, fat matter content; TFC, total fibers content; TCC, total carbohydrates content; RCC, reducing carbohydrates content; TGC, total glucides content; TEV, total caloric energy value

contents averages from 100 g aubergine dried sample are 51.55 mg total polyphenols, 29.78 mg tannins, and 0.95 mg flavonoids; while the vitamin C content is measured at 9.46 mg/100 g. From the main mineral elements, macro elements are measured between 8.51 ppm (Sodium) and 0.99% DM (phosphorous), when oligoelements oscillate from 0.018 ppm (copper) to 4.89 ppm (iron) as shown in Table 3.

Besides, from the antinutrients compounds, *S. aethiopicum gilo* provides more oxalates content (36.85 mg/100 g) and phytates content (27.74 mg/100 g) compared to *S. melogena* (25.63 mg/100 g and 23.74 mg/100 g, respectively).

4. DISCUSSION

The study shows a higher size of *Solanum melogena* fruit compared to *Solanum aethiopicum* gilo, a rounded aubergine species, whereas their medium circumferences do not vary. Thus, *S. melogena* obviously displays higher weight than *S. aethiopicum gilo*. Both aubergines are unvariously with great moisture value, over 92%. Such moisture contents are

Table 3. Micronutrients, polyphenols compounds and antinutrients contents in *S. aethiopicum gilo* and *S. melogena*

Charateristics		SAG	SM	T_{-value}	P_{-value}	General average
Polyphenols compounds (mg/100 g)	Total polyphenols	54.74±5.51[a]	48.36±6.89[a]	1.047	0.364	51.55±7.01
	Tannins	35.26±8.81[a]	24.3±2.65[a]	2.837	0.167	29.78±8.51
	Flavonoids	1.18±0.3[a]	0.73±0.39[a]	1.526	0.284	0.95±0.42
Vitamin and minerals	Vitamin (mg/100 g)	9.08±0.36[a]	9.85±2.04[a]	0.405	0.559	9.46±1.47
	Phosphorus (% DM)	0.92±0.13[a]	1.07±0.3[a]	0.349	0.587	0.99±0.26
	Potassium (% DM)	5.33±0.19[a]	7.74±1.28[a]	6.872	0.059	6.54±1.51
	Calcium (% DM)	0.40±0.039[a]	0.81±0.2[a]	7.167	0.055	0.60±0.25
	Magnesium (% DM)	0.57±0.06[a]	0.74±0.16[a]	1.884	0.242	0.65±0.14
	Sodium (PPM)	7.21±0.4[a]	9.82±1.75[a]	4.234	0.109	8.51±1.82
	Iron (PPM)	4.44±0.3[a]	5.35±0.68[a]	2.912	0.163	4.89±0.7
	Manganese (PPM)	2.30±0.16[a]	2.23±0.19[a]	0.144	0.723	2.26±0.18
	Zinc (PPM)	0.25±0.13[a]	0.31±0.13[a]	0.206	0.673	0.28±0.13
	Copper (PPM)	0.02±0.008[a]	0.02±0.005[a]	0.250	0.643	0.018±0.007
Antinutrients (mg/100 g)	Oxalates	36.85±5.63[a]	25.63±2.72[b]	9.637	**0.036**	
	Phytates	27.74±0.86[a]	23.74±1.90[b]	11.046	**0.029**	

Per raw, values followed by different lower scripts are statistically different at 5% significance. T_{-value}, value of the statistical Student T- test; P-value, value of the statistical probability test. SAG, Solanum aethiopicum gilo; SM, Solanum melogena close to that revealed from onion variety V1310 (90.44%) by Konate et al. [20]. The high moisture content of aubergines is disadvantageous for their preservation since the crops could be submitted to rapid post-harvest change and rotting. This phenomenon has been previously observed from ripe palm fruit by Ali et al. [21].

S. melogena is more provided with proteins (1.81%) compared to *S. aethiopicum gilo*. But both aubergines contain similar and lower lipids rate (0.12 and 0.12%), that is closed to the 0.14% lipid content in cooked spinach [22]. Their total glucides content are also lower (5.33% and 4.50%). Thus, they are not considered as glucides products since the glucides values are more strengthened from the common starchy products such as sweet potato (28.5%) according to the FAO [23]. In evidence, the aubergines are legumes crops and are not really used as source of carbohydrates, nor lipids and proteins. So, they are advisable in low-calory dietaries.

The studied aubergines also display similar fibre content around 2.35%, a lower value compared to the 3.92% fibre recorded with the fresh dough processed from the new shoots tuber of *Borassus aethiopum* as reported by Niamke et al. [24]. However, these aubergines could be significant sources of dietary fibers that are essential for the digestive balance in the intestinal duct and the stomach. Indeed, dietary fibers are factors of healthy body. Many studies have shown opposite correlation between consumption of dietary fibers and the upcoming of colon cancer. Dietary fibers can complex with carcinogenic molecules, thus preventing their contact with the colon and facilitating their excretion [25,26]. They account laxative role and help against colorectal cancer. They also usually drop the blood glucose, HDL-cholesterol, LDL-cholesterol, and so contribute in reduction of coronary heart disease [27]. Consumption of aubergines may therefore increase gastric volume allowing thus to feel the satiety state more quickly [26,28].

Vitamin C is measured in both aubergines below 10 mg/100 g. The consumption of these aubergines added with other vegetables richer in vitamins would be more beneficial. Vitamin C contributes in healthy bones, cartilage, teeth, and gums. It also protects against infections, accelerates healing and promotes the absorption of iron.

Significant total polyphenols contents (around 50 mg/100 g) are recorded from the studied aubergines, with any statistical change per variety. Most important parts of these polyphenols run for tannins (around 30 mg/100 g), while flavonoids are scarcely measured (1 mg/100 g). Polyphenols are credited with numerous health benefits, such as reduction of cardiovascular concerns, inflammatory or neuro-degenerative diseases, cancer prevention, antiplatelet effects, blood pressure regulation, *etc*. [29]. But, according to the predominance of tannins, aubergines could not be easily consumed fresh and their heating during cooking submits polyphenols biomolecules to degradation. Nevertheless, the heating process is affordable for succeeding in degradation of antinutrients components (oxalates and phytates) also highly found in the aubergines studied. Otherwise, these antinutrients could counteract the absorption of iron, zinc and calcium [30].

From their mineral composition, the aubergines studied are provided with the same contents in macro elements (Ca, P, Mg, Na, K) and oligo-elements (Fe, Zn, Cu, Mn). It's widely known that the major nutritional concerns from populations in developing countries are about deficiencies regarding proteo-energy nutrients and micro-nutrients especially minerals. The mineral elements are involved in a wide range of functions in the body, namely mineralisation, control of hydric balance, enzymatic and hormonal systems, the muscular system, the nervous and immune systems [22,20]. Thus, the essential nutrients are recommended in food intake according to Martin [31] and Konate et al. [20]. As overall legumes, aubergines are great source of mineral elements as strengthened by the current works. These raw crops are available in sufficient quantities in rural areas, and their use in diversified diet could be highly recommended for local populations.

4. CONCLUSION

The aubergines *Solanum aethiopicum gilo* and *Solanum melogena* contain macronutrients (carbohydrates, proteins, lipids) and several micronutrients (mineral elements, polyphenols, and vitamin) that highlight their significant nutritional potential. In addition, they records significant dietary fibers that regulate the appetite and the digestion. Both aubergines have closer nutritional potential. But, they should be processed for the degradation of the antinutrients compounds prior to their safe consumption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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